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An Investigation of the Relationship between the Biomass Energy Consumption, Economic Growth and Oil Prices

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Abstract

This paper investigates the causality analysis among biomass energy consumption, oil prices and economic growth in Austria, Canada, Germany, Great Britain, Finland, France, Italy, Mexico, Portugal and the U.S. by using the autoregressive distributed lag bounds testing (ARDL) method, Granger causality and Toda and Yamamato non-causality test. The dataset covers the 1970-2013 period. Although many papers have explained the relationship between oil prices and economic growth since 1970, papers have not focused the relationship among biomass energy consumption, oil prices and economic growth. This paper focused the relationship because it was accepted the biomass energy is affected by economic growth and the oil price. For Austria, Germany, Finland and Portugal, the Granger causality test determined the evidence that the conservation hypothesis is supported. In state of U.S., the feedback hypothesis highlights the interdependent relationship between biomass energy consumption and economic growth. Tado Yamamoto test determined, for Austria, Germany, Finland and Portugal, the conservation hypothesis is supported. In state of U.S., the feedback hypothesis highlights the interdependent relationship between biomass energy consumption and economic growth.

Keywords: Economic Growth, Bıomass energy, ARDL, VEC, Granger Causality, Toda and Yamamato non-causality test

1. Introduction

The economic system depends on traditional and modern energy. Energy consumption—especially biomass energy consumption—is old as humanity. Biomass is the only organic petroleum substitute that is renewable and is used to meet a variety of energy needs, including generating electricity, heating homes, fueling vehicles, and providing processed heat for industrial facilities (Ayres et.al 2007; Surmen, 2002). The term “biomass” is used for any plant material available for harvesting for a wide variety of possible uses such as food, building materials and fuel. Biomass can be used as direct substitutes for fuels or they can be processed into liquid fuels as oils and alcohol (Slupek et.al, 2000; Topcu and Ulengin, 2004; Balat et.al 2006; Balat, 2007). Biomass energy is most popular renewable energy in World in recent years.

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Fossil energy resources such as coal, oil, and natural gas have limited reserves, they are non-renewable, and can cause environmental pollution. These days, human beings are facing the dual pressure of economic growth and environmental protection, while energy problems are the basic problem related to national security and sustainable economic and social development (Chheda and Dumesic, 2007; Demirbas and Balat 2006; Jun et.al, 2011).

Biomass is a carbon-neutral form of energy that offers a potential alternative source of energy as a substitute for fossil fuel to will help mitigate climate change (Gumartini,2009). Biomass energy is the only renewable carbon energy, and with its virtues of low sulphur, low nitrogen, low ash, nearly zero-net CO_2 emission, and adequate sources, people are increasingly regarding and supporting its development and consumption (Chheda and Dumesic, 2007; Demirbas and Balat 2006; Jun et.al, 2011; Zhang et.al, 2011).

This paper will discuss the relationship among biomass energy consumption, oil prices, and economic growth. Many papers have explained the relationship between oil prices and economic growth since 1970. The existence of a negative relationship between oil prices and macroeconomic activity, or the asymmetric effects of oil prices were developed by Hamilton (1983) and Hooker (1996), who supported Hamilton's results. Other papers from this perspective were developed by Mork (1989), Hoover and Perez (1994), Lee et al., (1995), Hamilton (1997a, 1997b, 2003), Federer (1996), Balke et.al. (2002) and Bildirici, Alp and Bakırtaş (2011a, 2001b). The oil price affects both the economic growth and the rate of biomass energy consumption. The contribution of this paper is to analyse the relationship among biomass energy, oil price and GDP.

Economic background is located in the second section. Econometric theory and methodology are identified in the third section. The fourth section consists of the empirical results while the last section includes conclusions and policy implications.

2. Economic Background

Rural and poor urban households are the main consumers of traditional biomass energy because the alternative energy sources are very expensive. Commercial energy requires a well-developed infrastructure that is absent in many rural households. Therefore, traditional biomass energy is accessible for rural and urban poor households. Access to clean and affordable energy is essential to supply of heat, light and power to rural and urban poor areas as well as for other benefits such as the generation of income and health improvement (Gumartini 2009). Since the governments of many developed countries encourage the consumption of biomass energy as an alternative energy source, the share of modern biomass energy consumption in total energy consumption is continously increasing (Best and Christensen, 2003). Policy makers and theorists accept that there is value added in terms of the potential for increasing employment opportunities, enhancing energy security, generating income through job creation, and the development of a strong export industry, as well as the environmental benefits (Domac 2005).

The share of biomass energy in the total energy consumption varies among countries, but in general, the dependency on biomass energy is higher in poorer countries than in others. At present, Finland derives more than 20 percent of its total primary energy supply from biomass, while Sweden, Austria, and Australia have lower shares, about 17, 11 and 3.3 percent respectively (Gumartini 2009; Sadler, et.al. 2004). The main factors contributing to the difference in biomass energy consumption are urbanization, economic development and growth, standard of living (Dzioubinski, Chipman 1999), oil prices, and the number of people living in rural areas.

Biomass energy (traditional or modern) and/or fossil energy are essential for production, but standard macro-economic books employ capital and labor without energy in production functions while assuming energy as an intermediate product of the economy[1]. Many of today's models of long-term economic activity assume that changes in the energy supply or demand have no significant impact on economic growth (Ayres, Turton and Castenc 2007).

The literature on the causal relationship between biomass energy and economic growth is very sparse. Recently, Payne (2011), Bildirici (2012a,b;2013:2014) investigated the causal relationship between biomass energy consumption and economic growth by the ARDL method[2].

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[1] Many papers challenged the assumptions about energy made by macro-economics textbooks and discussed the importance of energy in economic growth. Kraft and Kraft (1978), Berndt (1978), Akarca and Long (1980), Proops (1984), Yu and Hwang (1984), and Erol and Yu (1987) investigated the relationship between energy consumption and economic growth in context of Granger Causality. The experiences of countries showed that energy plays a important role in their economic and industrial development, not only as a key input such as labor or capital, but also as a key factor in improving the quality of life (see Rosenberg (1998); Bildirici and Kayıkçı (2012) Bildirici, Bakırtaş and Kayıkçı (2012).

[2] According to Bildirici(2012), there is unidirectional causality from GDP to biomass energy consumption for Colombia and there is unidirectional causality from biomass energy consumption to GDP for Bolivia, Brazil and Chile. There is bi-directional causality for Guatemala. According to the

The causal relationship between biomass energy consumption and economic growth can be synthesized into four testable hypotheses. 1. *The growth hypothesis:* the biomass energy consumption has a significant impact on economic growth and/or complements labor and capital in the production process[3]. 2. *The conservation hypothesis:* there is unidirectional causality from economic growth to biomass energy consumption[4]. 3. *The feedback hypothesis:* highlights the interdependent relationship between biomass energy consumption and economic growth[5]. 4. *The neutrality hypothesis* is supported by the absence of causality between biomass energy consumption and economic growth[6].

This paper is the first study in the literature that uses cointegration techniques to analyse the relationship between biomass energy consumption, oil price and economic growth. The following demand function for biomass energy consumption will be written as,

$$BMC = f(Y, OP), \quad (1)$$

where, BMC is biomass energy consumption, Y is the real GDP and OP is the crude oil price. Expressing relation (1) in log-linear form, it is obtained the following econometric specification,

$$bmc_t = ao + a_1 y_t + a_2 po_t + e_t \quad (2)$$

Lower case letters show that the variables are expressed in logarithms, e_t is the error term and a_0, a_1, a_2 are parameters to be estimated. The income elasticity for biomass energy consumption and the cross price elasticity for a competitive product are expected to be positive.

3. Methodology

3.1. Research Goal

In the study, we aim to evaluate the long-run and short-run dynamics between biomass energy, economic growth and oil prices for Austria, Germany, Finland, Portugal, USA, Canada, France, Mexico and Great Britain. For this purpose, ARDL cointegration approach of Pesaran et.al. (2001) and Granger-causality analyses are performed.

3.2. Research Methodology: ARDL Cointegration and Causality Analyses

To investigate the causality between biomass energy consumption (BMC), real GDP (Y) and oil prices (OP) for 10 countries, the paper employed the ARDL approach of cointegration developed by Pesaran (1997) and Pesaran and Shin (1999)[7]. Recently, ARDL has become popular due to the low power and other problems associated with Johansen(1988), Engle-Granger (1987) and Johansen and Juselius (1990). The ARDL cointegration approach has numerous advantages over other cointegration methods. First, the ARDL procedure can be applied if the regressors are I(1) and/or I(0), while the Johansen cointegration techniques require that all variables in the system be of equal order of integration. The ARDL can be applied irrespective of whether underlying regressors are purely I(0), purely I(1) or mutually cointegrated and therefore do not need unit root pre-testing. Second, while the Johansen cointegration techniques require large data samples for validity, the ARDL procedure is a statistically more effective in determining the cointegration relationship in small samples. Third, the ARDL procedure allows the variables to have different optimal lags. Finally, the ARDL procedure employs only a single reduced form equation, while the other cointegration procedures estimate the long-run relationship within a context of system equations.

The ARDL approach to cointegration involves two steps for estimating the long-run relationship (Srinivasan, Santhosh and Ganesh (2012). The first step is to investigate the existence of a long-run relationship among all variables in the

long-run causality result, there is bi-directional causality for all countries. Bildirici (2012b) investigated the short-run and long-run causality analysis between biomass energy consumption and economic growth in the selected 10 developing and emerging countries by using the ARDL testing approach of cointegration and vector error-correction models.

[3] The growth hypothesis is confirmed if an increase in biomass energy consumption causes an increase in economic growth. The energy conservation policies which reduce biomass energy consumption adversely affect economic growth.

[4] In this case, energy conservation policies oriented toward the reduction of biomass energy consumption may not have an adverse impact on economic growth.

[5] The feedback hypothesis is substantiated by the presence of a bidirectional causality between biomass energy consumption and economic growth. This complementary relationship opens the possibility that energy conservation policies that reduce biomass energy consumption may affect economic growth. Such fluctuations in economic growth will be transmitted back to biomass energy consumption.

[6] Under this hypothesis, the reduction in biomass energy consumption through energy conservation policies will not affect economic growth.

[7] Some of the papers that used the ARDL approach in the energy literature are Squalli (2007), Narayan and Smyth (2005a, 2005b), Narayan and Singh (2007), Squalli (2007), Ghosh (2002), Odhiambo (2009 a,b) Wolde-Rufael Y. (2006), Bildirici and Kayıkçı (2012) and Bildirici, Bakırtaş and Kayıkçı (2012) for energy (electricity) consumption-economic growth literature and Bildirici (2012 a,b) for biomass energy consumption-economic growth literature.

equation under estimation. The ARDL-UECM model for the standard log-linear functional specification for the bmc variable is presented as: $\Delta bmc = \lambda_0 + \sum_{i=1}^{m} \alpha_i \Delta bmc_{t-i} + \sum_{i=0}^{n} \vartheta_i \Delta y_{t-i} + \sum_{i=0}^{k} \delta_i \Delta op_{t-i} + \varphi_1 bmc_{t-1} + \varphi_2 y_{t-1} + \varphi_3 op_{t-1} + \varepsilon_t$ (3)

where Δ is the first difference operator and and ε is the white noise term. An appropriate lag selection was based on the Akaike Information Criterion (AIC). The bounds testing procedure was based on the joint F-statistic or Wald statistic to test the null hypothesis of no cointegration. The joint significance of coefficients for lagged variables was tested with F statistics calculated under the null. The null hypothesis of no cointegration among the variables in Eq. (3) and Eq. (4) are against the alternative hypothesis. The null hypothesis of no cointegration among the variables in Eq. (3) is $H_0: \varphi_1 = \varphi_2 = \varphi_3 = 0$ against the alternative hypothesis $H_1: \varphi_1 \neq \varphi_2 \neq \varphi_3 \neq 0$. In the second step, if cointegration is established, the conditional ARDL long-run model for bmc can be estimated as:

$$bmc = \lambda_0 + \sum_{i=1}^{m} \alpha_i bmc_{t-i} + \sum_{i=0}^{n} J_i y_{t-i} + \sum_{i=0}^{k} \delta_i op_{t-i} + u_t \quad (4)$$

In the third stage, the short-run dynamic parameters are obtained by estimating an error correction model associated with the long-run estimates:

$$\Delta bmc = \lambda_0 + \sum_{i=1}^{m} \alpha_i \Delta bmc_{t-i} + \sum_{i=0}^{n} \vartheta_i \Delta y_{t-i} + \sum_{i=0}^{k} \delta_i \Delta op_{t-i} + \zeta\, ECM_{t-1} + e_t \quad (5)$$

where residuals e_t is independently and normally distributed with zero mean and constant variance and ECM_{t-1} is the error correction term. ζ is a parameter that indicates the speed of adjustment to the equilibrium level after a shock. It shows how quickly variables converge to equilibrium and it must have a statistically significant coefficient with a negative sign.

3.2.1. Granger Causality Analysis

In the last stage, we used the Granger (1969) and Toda and Yamamoto(1995) causality tests. ARDL approach tests if the existence or absences of long-run relationship between the BMC, the Y and oil price, but it do not determine causal relationship[8]. In the paper, we followed the two-step procedure as in Engle and Granger model to examine the causal relationship. The Vector Error Correction (VEC) model used to analyse the relationships between the variables was constructed as follows:

$$\Delta bmc = \lambda_0 + \sum_{i=1}^{m} \alpha_i \Delta bmc_{t-i} + \sum_{i=1}^{n} \vartheta_i \Delta y_{t-i} + \sum_{i=1}^{k} \delta_i \Delta op_{t-i} + \zeta_2 ECM_{t-1} + \varepsilon_{1t} \quad (6)$$

$$\Delta y = B_0 + \sum_{i=1}^{m} \theta_i \Delta py_{t-i} + \sum_{i=1}^{n} \gamma_i \Delta bmc_{t-i} + \sum_{i=1}^{k} \lambda_i \Delta op_{t-i} + \zeta_1 ECM + \varepsilon_{2t} \quad (7)$$

$$\Delta op = \nu_0 + \sum_{i=1}^{m} \mu_i \Delta op_{t-i} + \sum_{i=1}^{n} \upsilon_i \Delta bmc_{t-i} + \sum_{i=1}^{k} \kappa_i \Delta y_{t-i} + \zeta_3 ECM + \varepsilon_{3t} \quad (8)$$

where residuals ε_t are i.i.d. and is normally distributed with constant variance. ECM_{t-1} is the error correction term resulting from the long-run equilibrium relationship. ς defines the speed of adjustment to the equilibrium level after a shock. Short-run or weak Granger causalities are obtained by testing $H_0: \vartheta_i = \delta_i = 0$, $H_0: \gamma_i = \lambda_i = 0$ and $H_0: \upsilon_i = \kappa_i = 0$ in Equations (6,7 and 8) and long-run Granger causalities are by testing $H_0: \zeta_1 = 0$, $H_0: \zeta_2 = 0$ and $H_0: \zeta_3 = 0$.

3.2.2. **Toda and Yamamoto Test**

Certain shortcomings of the traditional Granger causality tests have been evaluated by the Toda and Yamamoto (1995) to obtain improved causality results under cointegration for variables with possibly different integration degrees. Granger Causality tests are based on null hypotheses formulated as zero restrictions on the coefficients of the lags of the variables (Olajide, 2010)[9]. Toda and Yamamoto(1995) suggest a modified Wald test for restrictions on the parameters of a VAR(k), MWALD (where k is the lag length in the system). This test has an asymptotic χ^2 distribution when a VAR(k + d_{max}) is estimated. The MWT test has a comparable performance in size and power to

[8] Ciarreta and Zarraga (2007) applied the standard Granger causality test in a VAR for the series in the first differences to achieve stationarity. They also evaluated the Toda and Yamamoto (1995) causality approach and showed that the results are robust to different methodologies. For a discussion of causality analyses, readers are refered to Dolado and Lutkepohl (1996).

the LR and WALD tests (Esso, 2010; Shan and Tian, 1998). MWT test needs to determine the maximal order of integration d_{max} in the model and construct a VAR in their levels with a total of p = (k + d_{max}) lags. For d=1, the lag selection procedure is valid since k=l=d. If d=2, then the procedure is also valid unless k=1. The MWT statistic is valid regardless whether a series is 1(0), 1(1) or 1(2), noncointegrated or cointegrated of any arbitrary(Abdul et.al., 2000).

The non-causality model used to analyse the relationships between the variables was constructed as follows:

$$bmc = \alpha_0 + \sum_{i=1}^{m} \varphi_i bmc_{t-i} + \sum_{i=m+1}^{m+d_{\max}} \varphi_{2i} bmc_{t-j} + \sum_{i=1}^{m} \delta_i y_{t-i} + \sum_{i=m+1}^{m+d_{\max}} \delta_{2i} y_{t-j} + \sum_{i=1}^{m} \phi_i op_{t-i} + \sum_{i=m+1}^{m+d_{\max}} \phi_{2i} op_{t-j} + \in_{1t} \quad (9)$$

$$y = \alpha_1 + \sum_{i=1}^{m} \beta_i y_{t-i} + \sum_{i=m+1}^{m+d_{\max}} \beta_{2i} y_{t-j} + \sum_{i=1}^{m} \gamma_i op_{t-i} + \sum_{i=m+1}^{m+d_{\max}} \gamma_{2i} op_{t-j} + \sum_{i=1}^{m} \lambda_i bmc_{t-i} + \sum_{i=m+1}^{m+d_{\max}} \lambda_{2i} bmc_{t-j} + \in_{2t} \quad (10)$$

$$op = \alpha_p + \sum_{i=1}^{m} \chi_i op_{t-i} + \sum_{i=m+1}^{m+d_{\max}} \chi_{2i} op_{t-j} + \sum_{i=1}^{m} \kappa_i bmc_{t-i} + \sum_{i=m+1}^{m+d_{\max}} \kappa_{2i} bmc_{t-j} + \sum_{i=1}^{m} \mu_i y_{t-i} + \sum_{i=m+1}^{m+d_{\max}} \mu_{2i} y_{t-i} + \in_{3t} \quad (11)$$

$\vartheta, \delta, \phi, \beta, \gamma, \lambda, \chi, \kappa, \mu$ are parameters of the model; d_{max} is the maximum order of integration suspected to occur in the system. $H_0 : \varphi_1 = 0$ show the null of non-causality from y to BMC and $H_0 : \phi_1 = 0 \quad \forall i = 1, 2, \ldots, m$ from op to bmc. The null hypothesis of no cointegration is not rejected when $\gamma_i = 0, \lambda_i = 0, \kappa_i = 0, \mu_i = 0$ [10]. In this paper, we involved with implementing the procedure in two step. Firstly, it is included the determination of the lag length (m) and secondly, it is the selection of the maximum order of integration (d_{max}) for the variables in the system. Schwarz Information was used to determine the appropriate lag order of the VAR(Esso:2010).

3.3. Sample and Data Collection

The dataset for Y for the selected countries is collected from the Worldbank WDI database and is calculated with year 2000 constant prices. The BMC data is gathered from the International Energy Agency. The oil prices represent the Brent petrol crude oil prices per barrel in American dollars and is taken from the British Petrol database. The BMC, oil prices and Y data is subject to natural logarithmic transformation and denoted as bmc, op and y throughout the analysis. As a result of the logarithmic transformation, it should be kept in mind that, the first differenced data will also represent the relevant growth rates of biomass consumption, the Y and petrol prices, respectively. The dataset covers the 1970-2013 period.

4. Analyses and Results

4.1. Unit Root Tests

The unit root tests are used to determine whether the variables are I(0) or I(1). The order of integration of the long-run relationships among the variables is defined using two types of unit root tests: (i) traditional ADF unit root test; and (ii) Lee and Strazicich(2004) unit root tests with structural breaks[11].The results are given in Table 1.

Table 1. Unit Root Test Results

	ADF		Lee and Strazicich			ADF		Lee and Strazicich	
	Level	First Difference	First Difference	Break Points		Level	First Difference	First Difference	Break Points
Austria					Canada				
Y	0.115	-4.015***	-3.206**	1972	Y	-0.980	-4.974***	-7.0929***	1982, 1991
BMC	0.373	-5.74***	-3.914***	1980	BMC	-2.744 (t)	-6.558***	-7.352***	1977,1992
Finland					France				
Y	-1.614	-4.827***	-3.266***	1973	Y	-2.957 (t)	-4.974***	-5.1580***	1980, 1986
BMC	-1.14	-4.074***	-5.822***	1972	BMC	-3.138 (t)	-6.558***	-4.7325***	1975, 1993

[9] Granger causality test in perspective of inferring leads and lags between integrated variables can cause spurious regression. The F-test is not valid unless the variables in levels are cointegrated (Abdul et.al, 2000). If the data are integrated but not cointegrated, it can be conducted causality tests by using the first differences (Esso, 2010). Alternative procedures have been developed to improve the size and power of the Granger no-causality test. The direction of causality is determined by Modified Wald Test (MWT) developed by Toda and Yamamoto(1995).

[10]Let $\varphi = vec(\varphi_1, \varphi_2, \ldots, \varphi_m)$ be vector of find mVAR coefficients. The Modified Wald Statistic for testing H_0 is $W = T\left(\hat{\varphi}' R' (R \hat{\sum}_{\in_t} R'\right)^{-1} R\hat{\varphi})$ where $\hat{\varphi}$ is the ordinary least squares estimate for the coefficient φ. $\sum_t$ is a consistent estimate for the asymptotic covariance matrix of $\sqrt{T}(\hat{\varphi} - \varphi)$. The test statistic is asymptotically distributed as a χ^2 with m degrees of freedom.

[11] The structural break in a macro economic time series is important for the stationarity analysis. Lee and Strazicich (2004) showed that the one-break minimum Lagrange multiplier (LM) unit root test tends to estimate the break point correctly and is free of size distortions and spurious rejections in the presence of a unit root with break.

Germany					Mexico				
Y	0.253	-4.475***	-4.478***	1973	Y	-1.34494	-5.957(t) ***	-6.8757***	1994, 1999
BMC	1.693	-5.74***	-5.748***	1973	BMC	-2.502 (t)	-3.816***	-6.5407***	1981, 1996
Portugal					Italy				
Y	-1.456	-4.327***	-3.322***	1972	Y	1.538	-4.1527 (t) **	-5.4081***	1986, 2004
BMC	-2.007	-4.691***	-3.2312***	1989	BMC	-0.446	-7.0339***	-6.0232***	1984, 1976
USA									
Y	-0.418	-3.591***	-3.407***	1975	Y	-1.4253 (t)	-3.3554 **	-5.7301***	1981, 2005
BMC	-0.3794	-5.045***	-3.852***	1993	BMC	-2.6466	-4.9891(t)***	-6.2901***	1993, 2000

Notes: For LS test critical values have changed according to position of break, λ(=T_{B}/T).The significance at 10%, 5% and 1% is denoted with *, ** and *** asterixes, respectively.

The ADF unit root test results suggest that the BMC and Y series are I(1) processes that become stationary after taking first differences for all countries analysed. For the Lee-Strazicich unit root tests, all variables are integrated of order one by taking structural breaks into consideration. [12].

4.2. ARDL Cointegration and Regression Results

Table 2 presents the results of the ARDL bounds tests. Dummy variables were attained following the break points observed in Table 1 to control for structural breaks.

Table 2: Bounds Testing for Cointegration

	Fy(y|bmc, op)	*Fbmc(bmc|y,op)*	*Fop (op|bmc, y)*		*Fy(y|bmc, op)*	*Fbmc(bmc|y,op)*	*Fop (op|bmc, y)*
Austria	1.33	15.1284**	1.0050	*Canada*	17.2265**	3.2324	2.3984
Germany	9.95072**	0.40490	1.9035	*France*	6.5325**	2.9516	1.4759
Finland	2.0278	9.8319**	2.2209	*Mexico*	2.2542	7.3112**	1.7620
Portugal	1.73802	13.9620**	2.1099	*Italy*	13.9043**	3.6790	2.7199
USA	2.2735	9.3720**	1.1212	*Great Britain*	2.8606	9.0489**	2.1170

Notes: *, ** denote significance at 10% and 5% significance levels. Critical values are taken from Pesaran et.al. (2001).

The notation in Table 2 is such that Fy(y|bmc,op) shows that the vector where y is the dependent variable and bmc and op are the explanatory variable. For a typical, for Germany, the F statistic calculated for Austria is 15.13 and is above the critical upper bound value showing that Fbmc(bmc|y,op) cointegration cannot be rejected. According to the results, the F-statistics are above the critical upper bound of Pesaran, suggesting evidence to reject the null hypothesis of no cointegration in favor of cointegration at 5 percent significance level among bmc, op and y for the countries analysed. The results suggest that there is no evidence of cointegration when the OP are taken as dependent variable. The results confirm the presence of a unique cointegration vector. For Austria, Finland, Great Britain, Mexico, Portugal and USA and the F tests suggests one cointegrating vector and the dependent variable is taken as the biomass consumption for these countries. For Canada, Germany, France and Italy, we observed a unique cointegrating vector, where the dependent variable is the real GDP.

4.3. The Results for Long-Run and Short Run Elasticities

The results in Table 2 suggested existence of a unique long-run relationship among variables of the ARDL type. Table 3 shows the long-run and short-run elasticities for the ARDL model.

Table 3. ARDL Results

Long-Run						*Short-Run ECM Model*					
	Bmc	*y*	*Op*	*Dummy*	R^2	*ECM*	*Bmc*	*Y*	*op*	*Dummy*	R^2
Aust.	-	0.22 (2.15)	0.24 (2.28)	0.17(2.03)	0.68	-0.22 (3.2)	-	1.05 (2.25)	0.06 (2.07)	0.01 (1.81)	0.64
Ger.	0.51 (2.58)	-	2.37(3.11)	0.12(1.98)	0.72	-0.13 (2.1)	-0.14 (2.82)	-	0.062(2.31)	0.75(1.91)	0.61
Fin.	-	1.06 (2.59)	0.35(2.00)	0.02 (2.02)	0.77	-0.32 (2.7)	-	0.23(2.97)	0.008(2.41)	0.12(1.89)	0.67
Por.	-	-0.49 (-2.5)	2.36(2.51)	1.01(1.89)	0.66	-0.30 (2.65)	-	-0.1(2.62)	0.05(1.90)	0.12(2.01)	0.74
USA	-	0.25 (2.42)	0.476(1.98)	0.27 (2.08)	0.86	-0.31(2.82)	-	-0.30(1.99)	0.06(4.25)	1.01(2.20)	0.81
Can.	7.90 (6.84)	-	0.12(0.33)	-4.65(-1.9)	0.99	-0.01(-2.1)	0.086(2.71)	-	0.001(0.31)	-0.05(-5.32)	0.51
FR	-0.31(3.89)	-	-0.07(-2.58)	0.02 (0.76)	0.99	-0.28 (-2.9)	-0.09(-2.68)		-0.02(-4.45)	0.006(0.78)	0.51
Mex.	-	-0.93 (-3.5)	-.17 (-3.67)	-.17 (-2.05)	0.98	-0.25 (-6.5)	-	-0.23(-3.16)	-0.04(-3.00)	-0.04 (-2.1)	0.56
Ita.	2.64 (0.86)	-	2.16 (3.49)	-6.1(-1.27)	0.99	0.01 (1.72)	-0.03(-2.71)		0.0013(0.1)	0.03 (1.96)	0.47
GB	-	-0.11 (-3.2)	0.02 (0.09)	0.09 (0.46)	0.99	-.49 (-2.39)	-	-0.06(-1.86)	0.008(0.09)	0.04(0.48)	0.38

Notes: t-values are given in paranthesis.

The long-run elasticities are statistically significant for a majority of the coefficient estimates. The elasticities are interpreted as usual, for instance, a 1 percent increase in per capita income, ceteris paribus, leads to a 0.22 percent

[12] As a typical, the oil price series is stationary in first differences (LS test statistic is calculated as -9.0582); further, the obtained break dates are 1977 and 1986. By testing the 1960-2013 period, we captured a significant break at the year 1973, as it should be expected. Since the biomass data starts from 1970, the dataset is analysed for the 1970-2013 period.

increase in the consumption of biomass energy for Austria. For Austria, Germany, Finland, Portugal and USA, all elasticity coefficients are statistically significant at 5% significance level. For Canada, the coefficient of *op* is not significant, whereas, *bmc* has significant and positive impact on *y*. For France, all coefficients are significant except for the dummy variable. For Mexico, all coefficients are statistically significant. For Italy, the longrun coefficient of bmc is not significant. Also, the dummy variable cannot be accepted at 5% significance level. For Great Britain, the longrun coefficient of OP is not significant, while Y has a negative impact on bmc, similar to the results obtained for Mexico and Portugal. The estimated cross elasticities display interesting results considering the signs of the coefficients. For Austria, Finland and USA, y has positive impact on bmc consumption, whereas, for Portugal, Mexico and Great Britain, y has negative impact on bmc consumption. For Germany, Canada, and Italy, y is the dependent variable and bmc consumption has positive impacts on Y. On the other hand, in France and Great Britain, bmc has negative impact on Y. OP have positive impacts on the dependent variables for the models estimated for Austria, Germany, Finland, Portugal and USA; and negative impacts on the dependent variables for Mexico. The oil price elasticity coefficients are statistically insignificant for Italy, Great Britain and France.

Regarding magnitudes of cross price elasticities in the short-run, the results are also given in Table 3, where the short-run regression results and the ECM mechanisms are reported. The results for the majority of the countries satisfy the ECM conditions, i.e. possessing negative signs and are less than 1. For Italy, there is an exception: though the ECM parameters are significantly positive, suggesting deviations from the long-run equilibrium. Further, the majority of the short-run elasticities are statistically significant at 5% significance levels. BMC has negative impact on the Y for Germany, France and Italy and bmc has positive impact in Canada's Y. For all of the countries, where the bmc is taken as the dependent variable, the Y growth rates have significant impacts. For Austria, Finland and Canada, the impact of Y growth rates on bmc consumption growth rates are significantly positive; whereas, for Portugal, USA, Mexico and GB, the impact of Y growth rates on bmc consumption growth rates are negative. Oil price growth rates have positive impacts on biomass consumption growth rates in the short-run for the countries, for which the biomass consumption is taken as the dependent variable. The results are as expected since the oil price increases are expected to increase the tendency towards biomass production and therefore, towards the bmc consumption.

Considering the evidence of a long-run relationship between variables, the long-run and short-run models are represented in the second step. The ECMs indicate that disequilibrium among op, y and bmc are corrected. The signs of the coefficients of the error correction terms are between -0.12 and -0.49 to provide stability for the model, one exception is for Canada, where the error correction terms is estimated as -0.011, as unexpectedly low. Except for Canada, the size of the error correction terms suggest a speed of adjustment ranging from 2 to 5 years for the evaluated countries.

4.4. **Stability**

There were single or multiple structural breaks in the analysed period due to economic crises, policy changes, and sharp shifts. CUSUM and CUSUM-Q tests were used to evaluate the stability of the parameters in the models estimated. These tests are different and more efficient than Chow tests; they do not require prior knowledge about the time of the structural breaks. The CUSUM and CUSUM-Q plots to check the stability of the long-run and short-run parameters. The results in Figure 1 included the CUSUM-Q tests only to save space. The results are given in the Appendix. The CUSUM-Q statistics stay within the critical bounds of 5 percent level of significance and the null hypothesis of all coefficients are stable cannot be rejected.

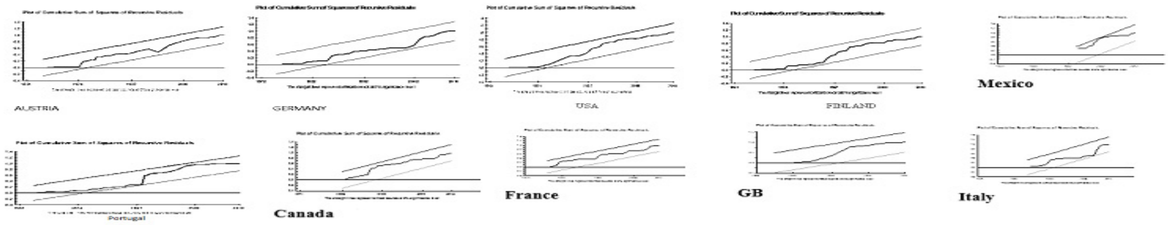

Figure 1. Stability Tests for the Countries Analysed

3.4.5. The Results for Granger Causality Tests

To evaluate the causality, the VAR representations with ECM forms are utilized. The ARDL method do not indicate the direction of causality, but since there is a long-run relationship among op, bmc and y, a causality relationship must exist in at least one direction. Table 4 summarizes the causality relationship among bmc, op and y.

The results in Table 4 show that Granger causalities were present implicitly via the ECM. The relationship between bmc and op shows a bidirectional causality from bmc to op for Austria, Germany, Finland, Portugal, and the U.S. For the relationship between y and op, a unidirectional causality from y to op for Austria was determined, along with a unidirectional causality from op to y for Germany and bidirectional for the Finland, Portugal. For Finland and Portugal, the result of bidirectional causality is not in the excepted direction. For Austria, we observed a unidirectional causality from y to op. For the countries analysed afterwards, namely, Great Britain, Canada, France, Mexico, the causality between the variables cannot be accepted. This result is in contrary of the results obtained in the ARDL analysis. On the other hand, the ECM terms have significant impacts for Canada on the bmc and op; significant impact on bmc in France and Mexico; significant impacts on y in Italy. The ECM terms have significant impacts in Great Britain on bmc. The Granger causality results gave unexpected causality results. The investigation of the reasons behind this result is related to the characteristics of the data analysed and the application of the ARDL method under structural breaks[13].

Table 4. Granger Causality

	Granger Causality		Toda-Yamamoto Causality Test			Granger Causality		Toda-Yamamoto Causality Test	
	Δy→Δ bmc, Δy→Δop Δbmc →Δy, Δbmc →Δop Δop →Δy, Δop →Δbmc	ECM→ Δy ECM→ Δbmc ECM → Δop	Δy→Δ bmc Δy→ Δop Δop → Δbmc	Δbmc →Δy Δop →Δy Δbmc→ Δop		Δy→Δ bmc, Δy→Δop Δbmc →Δy, Δbmc →Δop Δop →Δy, Δop →Δbmc	ECM→ Δy ECM→ Δbmc ECM → Δop	Δy→Δ bmc Δy→ Δop Δop → Δbmc	Δbmc →Δy Δop →Δy Δbmc→ Δop
Aus.	14.5117***, 4.1452*** 0.3481, 24.0152*** 0.3315, 4.0468**	20.5179*** 10.8219*** 40.168***	10.113*** 0.3481 7.3315**	1.1452 0.0152 0.7856	GB	0.007, 0.018 0.032, 0.010 1.776, 0.119	0.113 3.414* 0.195	13.1214*** 1.1337 15.786***	0.9875 17.665*** 1.452
Ger.	1.1052, 1.1035 87.012***, 9.5201*** 17.822***, 90.206***	33.92*** 92.159*** 47.39***	11.105*** 1.1035 17.012***	0.012 11.479*** 1.822	Can.	0.315, 2.374 0.513, 0.504 0.401, 0.383	1.391 3.198* 7.206***	7.001** 9.746*** 10.665***	9.789*** 11.759*** 10.856***
Fin.	46.622***, 45.9574*** 14.512***, 22.21*** 4.1622**, 46.0258***	7.2852*** 27.607*** 47.021***	46.622*** 1.1512 0.1622	1.9574 13.102*** 46.028	FR	2.569, 0.237 2.673, 2.081 5.306*, 1.659	2.436 6.232** 1.803	9.1012*** 1.1112 9.889***	0.1998 0.01333 0.5456
Por.	87.836***, 89.135*** 10.853***, 9.9856*** 32.143***, 15.175***	15.453*** 75.453*** 40.785***	10.083*** 0.0086 12.143***	1.135 10.85*** 1.175	Mex	1.334, 0.794 2.221, 2.092 0.008, 0.312	1.941 5.583** 0.151	15.111*** 10.121*** 13.125***	9.998*** 9.1962*** 13.456***
USA	19.204***, 28.758*** 30.305***, 54.785*** 35.456***, 36.758***	65.623*** 42.785*** 25.365***	27.126*** 9.9836*** 11.893***	8.886*** 7.869** 10.109***	Ita.	0.159, 2.156 14.725***, 1.889 4.787*, 2.161	8.533** 2.757 0.403	15.668*** 6.7851** 15.789***	0.0145 19.526*** 1.07859

Granger causality results gave unexpected causality results. As a second test, Toda-Yamamoto Causality test was used. According to the results for Toda-Yamamoto Causality tests, For Finland and Austria that the conservation hypothesis is supported. The growth hypothesis was accepted for Germany and Great Britain. For Canada, Mexico, Portugal and U.S., the feedback hypothesis highlights the interdependent relationship between bmc and y. Toda and Yamamato (1995) causality test determined that for Austria, Germany, Great Britain, Finland, France, Italy and Portugal that the conservation hypothesis is supported, energy conservation policies oriented toward the reduction of bmc may not have an adverse impact on y. In state of U.S. and Mexico, the feedback hypothesis highlights the interdependent relationship between bmc and y. The feedback hypothesis determine the possibility that energy conservation policies that reduce bmc may affect y. Such fluctuations in y will be transmitted back to bmc. For Germany, Finland and Portugal, it was determined unidirectional causality from op to y and from op to bmc. These results are as we expected.

5. Conclusion

This study used the ARDL method to analyse the relationship between BMC, OP and economic growth in Austria, Germany, Finland, Portugal, U.S, France, Mexico, Italy, Great Britain and Canada. To examine the causal relationships, we use the two-step procedure from the Engle and Granger model and Granger causality-Toda Yamamoto non-causality test. Firstly, the long-run relationship between the variables are evaluated by using the ARDL approach. Secondly, a dynamic VEC model is evaluated to test the causal relationships between biomass consumption, Y and OP.The results suggest that there is evidence on the long-run and causal relationships between BMC, OP and economic growth in countries analysed. The main findings of our study are as follows: (a) there is a unique long-term or equilibrium relationship between BMC, OP and economic growth in Austria, Germany, Finland, Portugal, U.S, Canada, Mexico, Italy, France and Great Britain; (b) We found the different results for Canada and Great Britain since two cointegration vectors are obtained, (c) Series are subject to structural breaks and possibly

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[13] As observed, the L-S unit roots tests reported showed that there are structural breaks at different dates. Though certain dates collide for certain bmc, y and op series, for the majority of the sample, the breaks cannot be considered as co-breaks. Further, after including the dummy variables for each break observed, the dummies fail to capture the structural change in the variables analysed considering that the parameters are insignificant for the regressions of certain countries.

nonlinearity since dummy variables fail to capture or augment the results, (d) Granger causality result gave unexpected causality results. The second causality test being Tado Yamamoto Causality test was used. For Austria, Germany, Finland and Portugal, the conservation hypothesis is supported. In state of U.S., the feedback hypothesis highlights the interdependent relationship between BMC and economic growth.

Considering the findings; for Austria, Germany, Finland and Portugal, the conservation hypothesis is supported. For U.S., the feedback hypothesis highlights the interdependent relationship between BMC and economic growth. Among Canada, France, Italy, Mexico and Great Britain; only for France, Italy and Great Britain, we observe causality from the OP to GDP growth rates. Further, biomass consumption also has impacts on GDP growth rates for Italy and Great Britain. The long-run ECM factors also play crucial role on biomass consumption for Canada, France and Mexico. Additionally, the ECM factors have important causality results on the GDP growth rates in Italy and Great Britain. However, the results cannot lead to the conclusion that feedback hypothesis exists for this countries as for the case for USA. Toda-Yamamoto tests are evaluated at the second stage. According to the results, for Austria, Germany, Great Britian, Finland, France, Italy and Portugal, the conservation hypothesis is supported. For U.S. and Mexico, the feedback hypothesis highlights the interdependent relationship between BMC and economic growth.

The empirical results of this study provide policymakers a better understanding of between BMC, OP and economic growth nexus to formulate energy policies in these countries. As a policy implication; Austria, Germany, Great Britian, Finland, France, Italy and Portugal and U.S. should invest in biomass energy infrastructure and step up energy conservation policies to avoid a reduction in BMC adversely affecting economic growth. However, without incorporating the structural breaks adequately, either through dummy variable based approaches lead to misleading conclusions. Therefore, the ARDL approach might lead to problematic errors in policies. These findings demonstrate that energy policies aimed at improving the energy infrastructure and increasing the energy supply are the appropriate options for these countries, since BMC increases the income level. In terms of the empirical approaches, the econometric methodology should be augmented to incorporating continuous transition functions to model nonlinearity or breaks without loss of degrees of freedom.

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